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Evaluating airline operational performance: A Luenberger-Hicks-Moorsteen productivity indicator

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ABSTRACT

This study proposes a by-production Luenberger-Hicks-Moorsteen indicator that includes undesirable outputs, here CO_2 emissions, in airline performance analysis. We use capital and staff as inputs and tonne-kilometres available as a desirable output to evaluate operation stage efficiency and productivity of the world's major airlines between 2007 and 2013. Our results demonstrate European airlines are relatively stronger performers in terms of both pollution-adjusted operational efficiency and productivity. Middle-Eastern airlines have made gains in terms of output growth but perform poorly in terms of pollution-adjusted productivity, evidence that ETSs may produce greener airlines.

1. Introduction

The US Environmental Protection Agency (EPA) stated recently that 'greenhouse gas emissions from airplanes are dangerous to human life', and therefore should be subject to further emission-reducing regulations (EPA, 2015, p. 1). In addition to the immediate threat to human lives, the Intergovernmental Panel on Climate Change (IPCC) has forecast that aviation emissions will make an important contribution to the build-up of greenhouse gases (GHGs) in the atmosphere, heavily contributing to global warming in the next few decades (IPCC, 2007). Consequently, over the past few years, national and international attempts to curb climate change have forced governments to implement strategies to reduce anthropocentric CO_2 (carbon dioxide) emissions in general, and by the aviation industry in particular. As significant users of fossil fuels, airline industries have been included in planned and operational emission trading schemes (ETSs) in several jurisdictions across the world. They were considered for inclusion in the first phase of the European ETS in January 2005. In January 2012 it became the first trading scheme to cover CO_2 emissions from air travel, quickly followed by Australia and New Zealand in July 2012. In China, the Shanghai ETS included six major airlines, making them subject to a price on carbon from November 2013

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onwards. In January 2015, another Asian country, South Korea, started its ETS covering six GHGs with a 30 per cent reduction target until 2020 and planned to put a price on emission from airlines. In the US, the mandatory trading under the RGGI (Regional Greenhouse Gas Initiative) founded in 2009 has, since 2013, included in the voluntary trading within the Western Climate Initiative (WCI) with the potential inclusion of airlines in British Columbia, California, Manitoba, Ontario and Quebec. In 2012, the US EPA also announced that market-based measures (MGMs) against aviation emissions need to be taken, but left the design of such measures to the International Civil Aviation Organization (ICAO).[1] Currently, several other countries (such as Brazil, Chile, Japan, Mexico, Russia, Turkey, Ukraine and Vietnam) have also considered an ETS as a viable solution to reduce their carbon footprint, indicating a substantial growth in ETSs worldwide that put a price on GHGs emission and require airlines to surrender permits equivalent to their footprint (ICAP, 2015). Coinciding with the establishment of ETSs, increases in fuel prices have provided additional incentives for airlines to reduce their carbon footprints, because fuel is among the top three cost items faced by airlines, accounting on average for up to one-third of their operating costs in 2013 and 20 per cent in 2016 depending on the price of Jet A/A-1 fuel (IATA, 2013, 2016). Airlines may respond to these new higher cost regulatory and economic environments by upgrading their fleet and introducing more fuel-efficient models, and adjusting operating practices to reduce fuel consumption and thus ease the financial burden (Sgouridis et al., 2011). In this context, it is pertinent and timely to produce a precise measure of airline performance. This study proposes a novel productivity indicator to measure airline pollution-adjusted operational efficiency and productivity changes. This measure can provide crucial findings and help policy makers to better understand the environmental performance of their national carriers (vis-à-vis their rivals) and gain a deeper insight into the effectiveness of ETSs in reducing airline emissions in different regions. This new indicator can also assist airlines understand their relative pollution-adjusted performance in order to eliminate existing shortcomings. Moreover, eco-conscious travelers may find our findings helpful to help them select services from more environmentally friendly airlines and so reduce their own carbon footprint.

In the non-parametric framework of data envelopment analysis (DEA), a common approach to analysing the relationships between multiple inputs and outputs and evaluating the relative efficiency of decision-making units (here, airlines), many models have been developed to account for undesirable outputs.[2] In these models, pollution has commonly been treated as an output under the weak disposability assumption, WDA (Färe et al., 1986, 1989). Although this approach has been widely used in both energy (Zhou et al., 2008; Chen, 2013a) and airline efficiency literature (e.g., Fukuyama et al., 2011; Chang et al., 2014; Li et al., 2016a), clear limits of this approach have been put forward in several studies (Førsund, 2009; Chen, 2013b). Among others, the WDA violates the materials balance principle which ensures every physical process occur within the limits of the laws of thermodynamics (Coelli et al., 2007). The by-production approach, introduced by Murty et al. (2012), is considered in the literature as a better alternative for avoiding such drawbacks (Chambers et al., 2014; Serra et al., 2014). This approach posits that complex systems are made of several independent processes (Frisch, 1965) and the global technology can be separated into sets of sub-technologies: one for the production of good outputs and one for the generation of bad outputs. In other words, the by-production approach draws on an explicit representation of the process that generates each type of output (good and detrimental outputs in this case). Then, the global technology implies interactions between several separate sub-technologies. Førsund (2017) has recently classified the by-production approach among the multi-equation modelling approaches and argued that an important advantage of this approach over other approaches (such as WDA, the strong disposability assumption and the slack-based models) is that it represents pollution-generating technologies by accounting for materials balance and therefore satisfies the physical laws. Discussing the limits of pollution-generating technologies, Dakpo et al. (2016) also confirmed that the by-production method offers some very promising opportunities, such as treating multiple types of outputs, in comparison to other existing approaches. Therefore, this study employs the by-production approach and also contributes to the efficiency analysis literature by offering a new by-production model which deals with the inclusion of undesirable outputs to provide a comprehensive analysis of operational performance of 33 major international airlines for the period 2007–2013.

In the area of productivity analyses, the Malmquist index is by far the most popular index for assessing the productivity of decision-making units (DMUs) over time, though it has several shortcomings (Arjomandi, 2011; Arjomandi and Seufert, 2014; Kerstens and Van de Woestyne, 2014; Arjomandi et al., 2015). O'Donnell (2008) argues that an adequate productivity index must be multiplicatively or additively complete. That is, a total factor productivity index (TFP) should be written as the ratio of an aggregate output to an aggregate input (multiplicative completeness) or as the difference of these aggregate values (additive completeness). Besides, TFP indices must satisfy a certain number of axioms and tests; monotonicity, homogeneity, identity, dimensionality, proportionality, time-reversal, factor-reversal and circularity tests are among the 20 key tests listed by Diewert (1992). However, the Malmquist index fails to satisfy these conditions. The Hicks-Moorsteen (HM) index, discussed in Bjurek (1996) and Lovell (2003), is proven to be a complete index (O'Donnell, 2008, 2010, 2012).[3] In this study, in addition to the above-mentioned contribution, we extend the Luenberger-Hicks-Moorsteen (LHM) productivity indicator of Briec and Kerstens (2004) to account for undesirable outputs in the framework of the by-production approach. The directional distance function (DDF) used in this study has the advantage of allowing for simultaneous changes in both good and bad outputs (Chung et al., 1997). Moreover, unlike the Malmquist index, our difference-based indicator possesses the advantage of dealing with zero and negative variables and also inherits of the translation invariance property.

[1] We would like to thank the anonymous reviewer for pointing out that non-market based solutions, e.g. technology standards, aircraft engine and technology improvements measures, had already been adopted by the US Government (FAA, 2012).

[2] DEA was first introduced by Charnes et al. (1978), after Farrell (1957) proposed the original idea of efficiency evaluation.

[3] This HM index is based on the ratios of Malmquist output and input productivity indices.